TITLE OF THE INVENTION

OPTICAL SYSTEM WITH IMAGE PRODUCING SURFACE CONTROL UNIT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Patent Application No. 2003-77705, filed November 4, 2003 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates, in general, to an optical system to inspect defective parts of a flat panel display (FPD), such as a liquid crystal display (LCD) and, more particularly, to an optical system to attain a uniform and clear image of an object when the object inclined relative to an optical axis of a lens of the optical system is photographed.

2. Description of the Related Art

[0003] When defective parts on an FPD, such as an LCD, are inspected, an inspection result of the FPD may be varied according to viewing angles due to a characteristic of a viewing angular field of the FPD. Thus, when the FPD is photographed to inspect the defective parts thereof, it is necessary to photograph the FPD at a variety of angles as well as a vertical position with respect to the FPD.

[0004] To solve the above problem, there was proposed an optical system in Korean Patent Laid-Open Publication No. 2003-52528. According to the above Korean Patent Laid-Open Publication, an object was inspected using a common optical system and an inclined optical system. The common optical system photographs a surface of the object at a vertical position above the object. The inclined optical system photographs the surface of the object at an inclined position with respect to the object at a predetermined angle.

[0005] In the inclined optical system according to the above-mentioned Korean Patent Laid-Open publication, a CCD camera (charge-coupled device camera) which photographs a picture of the object must be placed to satisfy a specific equation. However, the conventional inclined optical system has a problem in that reference points of distances used in the specific equation are indefinite, thus the CCD camera may not be placed at a desired position. The conventional

inclined optical system also has another problem in that it has no pickup unit to photograph the object at a variety of angles.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an aspect of the present invention to provide an inclined optical system capable of attaining a clear image of an object when an optical axis of a lens of the optical system is inclined relative to the object at a predetermined angle.

[0007] It is another aspect of the present invention to provide an optical system which is capable of clearly photographing an entire object at a variety of angles.

[0008] Additional aspects and/or advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0009] The above and/or other aspects of the present invention are achieved by providing an optical system, which includes a lens to refract light radiating from an object, an image producing surface to produce an image according to the light refracted by the lens, and an image producing surface control unit to control the image producing surface with respect to the object and/or the lens.

[0010] According to another aspect of the invention, the image producing surface control unit may include an angle control unit to control an angle between an optical axis of the lens and the image producing surface. The angle control unit may include a distance adjusting unit provided at a position spaced apart from a rotative shaft of the optical system, and an elastic member mounted at a first end thereof to a base of the optical system and at a second end thereof a the body of the optical system.

[0011] According to yet another aspect of the invention, the lens is mounted to the lens, and the image producing surface is mounted to the body. The body may be coupled to the base by the rotative shaft to rotate relative to the base. A central axis of the rotative shaft and the image producing surface may be placed on the same plane. The image producing surface may rotate with respect to the central axis of the rotative shaft disposed on the same plane.

[0012] According to still another aspect of the invention, the body may include an outer frame supported by the rotative shaft, an inner frame mounted to the outer frame to rotate around a

central axis of the outer frame, and a rear casing mounted to the inner frame and having the image producing surface mounted thereto. A charge-coupled device (CCD) may be provided at the image producing surface to convert the light radiating from the object into an electrical signal.

[0013] The above and/or other aspects of the present invention are achieved by providing an inclined optical system including a lens to refract light radiating from an object, and an image producing surface on which an image is produced using the light refracted by the lens. In this case, an optical axis of the lens is disposed at a predetermined angle with the object. When it is assumed that: the optical axis is expressed by X, an intersection point between a first main surface of the lens which faces the object and the optical axis X is expressed by a first main point O_1, and an intersection point between a second main surface of the lens which faces the image producing surface and the optical axis X is expressed by a second main point O_2; a first point on the object is expressed by A, a foot of the first point A in a direction perpendicular to the optical axis X is expressed by A_0, a distance between the foot A_o and the first main point O_1 is expressed by s_2, an image of the first point A produced on the image producing surface is expressed by A', a foot of a perpendicular from the image A' to the optical axis X is expressed by A'_0, and a distance between the foot A'_0 and the second main point O_2 is expressed by s'_2; and a second point on the object is expressed by C, a foot of a perpendicular from the second point C to the optical axis X is expressed by C_0, a distance between the foot C_o and the first main point O_1 is expressed by s_3, an image of the second point C produced on the image producing surface is expressed by C', a foot of in a direction the image C' perpendicular to the optical axis X is expressed by C'_0, and a distance between the foot C'_0 and the second main point O_2 is expressed by s'_3, the image producing surface is inclined relative to the optical axis X of the lens so that the distance s'_2 is shorter than the distance s'_3 when the distance s_2 is longer than the distance s_3.

[0014] According to another aspect of the invention, in the inclined optical system, when the first point A is set so that a distance between the foot A_0 and the first main point O_1 is farthest, and the second point C is set so that a distance between the foot C_0 and the first main point O_1 is nearest. When it is assumed that: a focal distance of the lens is expressed by f, an intersection point between the object and the optical axis X of the lens is expressed by B, a distance between the intersection point B and the first main point O_1 is expressed by s_1, an image of the intersection point B produced on the image producing surface is expressed by B', and a distance between the image B' and the second main point O_2 is expressed by s'_1, the

image producing surface is inclined relative to the optical axis X of the lens to satisfy the following Equation $1/s_1 + 1/s'_1 = 1/f$ and to satisfy at least one of the following Equations $1/s_2 + 1/s'_2 = 1/f$ and $1/s_3 + 1/s'_3 = 1/f$.

[0015] According to yet another aspect of the invention, in the inclined optical system, when it is assumed that: an intersection point between the first main surface and a line extending through the first point A and the second point C is expressed by D, and an intersection point between the second main surface and a line extending through the image A' and the image C' is expressed by E, the image producing surface is inclined relative to the optical axis X of the lens so that a line extending through the intersection point D and the intersection point E is parallel to the optical axis X.

[0016] The above and/or other aspects of the present invention are achieved by providing an inclined optical system, which includes a lens to refract light radiating from an object, and an image producing surface on which an image is produced using the light refracted by the lens, the lens and the image producing surface inclined in opposite directions relative to an optical axis of the lens.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and/or other aspects and advantages of the invention will become apparent and more readily appreciated from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings of which:

[0018] FIG. 1 is a sectional view of an optical system having an image producing surface control unit according to an embodiment of the present invention;

[0019] FIG. 2 is an exploded perspective view of the optical system of FIG. 1;

[0020] FIG. 3 is a sectional view to show a state where a surface of an object which is inclined relative to an optical axis of a lens of the optical system is photographed by the optical system of FIG. 1; and

[0021] FIG. 4 is a view to show a photographing principle of the optical system of FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Reference will now be made in detail to the preferred embodiment of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. The embodiment is described below in order to explain the present invention by referring to the figures.

[0023] FIG. 1 is a sectional view of an optical system 100 having an image producing surface control unit according to an embodiment of the present invention. FIG. 2 is an exploded perspective view of the optical system 100 of FIG. 1.

[0024] As shown in FIGS. 1 and 2, the optical system 100 includes a lens 10, a lens holder 11, a base 20, a body 50, and an angle control unit 70. The lens 10 refracts light radiating from an object T to be inspected, and is mounted to the lens holder 11. To the base 20 is mounted the lens holder 11. The body 50 is rotatably mounted to the base 20. The angle control unit 70 is provided on upper portions of both the base 20 and the body 50.

[0025] The body 50 includes a frame 51, a rear casing 52, and an image producing surface 60. The frame 51 is coupled to the base 20 by tilting shafts 22 to tilt relative to the base 20. The rear casing 52 is mounted to the frame 51. The image producing surface 60 is provided on a predetermined portion of the rear casing 52to produce an image (signal) according to the light refracted by the lens 10. The frame 51 includes an outer frame part 30 which is coupled to the base 20 by the tilting shafts 22, and an inner frame part 40 which is seated (disposed) in the outer frame part 30 to rotate around a central axis of the outer frame part 30. The rear casing 52 may be fixedly mounted to the inner frame part 40.

[0026] The lens 10 is held by the holder 11 to be disposed on a central portion of the lens holder 11. The lens holder 11 is seated (disposed) in a circular seating opening 21 provided on a central portion of the base 20. The outer frame part 30 is coupled to the base 20 by the tilting shafts 22 provided on both side ends of the base 20. To couple the outer frame part 30 to the base 20, shaft mounting holes 31 are provided on an outer surface of the outer frame part 30 at positions corresponding to the tilting shafts 22 of the base 20. On a central portion of the outer frame part 30 is provided a first seat opening 38 so that the inner frame part 40 is seated (disposed) in the seat opening 38 of the outer frame part 30. Further, a stepped portion 41 is provided along an outer edge of a front surface of the inner frame part 40, and a locking step 32 is inwardly projected from an edge of the outer frame part 30 corresponding to the first seat opening 38 so that the stepped portion 41 of the inner frame part 40 is seated (disposed) on the

locking step 32 of the outer frame part 30. A plurality of screw holes 33 are provided along the outer surface of the outer frame part 30. The inner frame part 40 is fastened to the outer frame part 30 by tightening a plurality of screws 34 into the outer frame part 30 through the screw holes 33.

[0027] The image producing surface 60 is provided on a central portion of a front portion of the rear casing 52 to produce an image according to the light passing through the lens 10 and impinging on the image producing surface 60. A charge-coupled device (CCD) is provided on a predetermined portion of the image producing surface 60 to convert the light into an electrical signal corresponding to the image of the object T. The electrical signal output from the CCD is transmitted to an image processing unit (not shown) to process the electrical signal. The rear casing 52 is seated (disposed) in a second seat opening 42 provided on a central portion of the inner frame part 40. Further, after the inner frame part 40 is seated in the first seat opening 38 of the outer frame part 30, the inner frame part 40 is fastened to the outer frame part 30 by tightening the screws 34 into the outer frame part 30 through the screw holes 33. In this case, because the inner frame part 40 is fastened to the outer frame part 30 by the screws 34, the inner frame part 40 may be loosened from the outer frame part 30 by manipulating the screws 34 when necessary. Thus, when the image producing surface 60 is required to rotate on a same plane, that is, when the image producing surface 60 is required to rotate with respect to its central axis (or optical axis) without tilting the image producing surface, the screws 34 are loosened from the screw holes 33 to allow the inner frame part 40 to rotate relative to the outer frame part 30. At this time, the rear casing 52 rotates along with the inner frame part 40, thus allowing the image producing surface 60 to rotate with respect to the same plane as the tilting shafts 22 to a desired angle.

[0028] The angle control unit 70 functions to control a tilting angle of the image producing surface 60 with respect to the base 20 of the lens 10. The angle control unit 70 includes a distance adjusting unit 71 and an elastic member 72. The distance adjusting unit 71 is provided at a predetermined portion of the outer frame part 30 to adjust a distance between the outer frame part 30 and the base 20, thereby adjusting the tilting angle of the image producing surface 60. The elastic member 72 is mounted at a first end thereof to the base 20 and at a second end thereof to the outer frame part 30. The distance adjusting unit 71 includes a thimble 73, a spindle 74, and a sleeve 75. The thimble 73 is a part of a micrometer to measure a distance and rotates around a central axis thereof. The spindle 74 advances or retracts along the central axis of the thimble 73 according to a rotating direction of the thimble 73. The sleeve

75 supports both the thimble 73 and the spindle 74. The elastic member 72 may be a tension spring to bias the base 20 in a direction toward the outer frame part 30.

[0029] To mount the distance adjusting unit 71 and the elastic member 72 to the outer frame part 30, a support bracket 23 upwardly projects from an upper end of the base 20, and a first support hole 24 is provided on a predetermined portion of the support bracket 23 to support the first end of the elastic member 72. Further, a mount bracket 35 upwardly projects from an upper end of the outer frame part 30, and a mount hole 36 is provided on a predetermined portion of the mount bracket 35 to mount the sleeve 75 of the distance adjusting unit 71 to the outer frame part 30. A second support hole 37 is provided on a predetermined portion of the mount bracket 35 around the mount hole 36 to support the second end of the elastic member 72. The mount bracket 35 and the sleeve 75 are coupled to each other using threaded portions formed thereon when a portion of the distance control unit 71 is inserted into the mount hole 36. The spindle 14 protrudes and is retreated with respect to the sleeve 75 so that the image producing surface 60 moves with respect to the base 20 and/or the lens 10 according to a rotation of the thimble 73 and/or a movement of the spindle 74.

[0030] In this case, the lens holder 11, the base 20, the outer framer part 30, the inner frame part 40, and the rear casing 52 are placed along an optical axis X of the lens 10, i.e., a central axis of the above-mentioned elements. In the present invention, a central axis of the tilting shafts 22 of the outer frame part 30 and the base 20 is preferably placed on the same plane as the image producing surface 60.

[0031] The present invention further provides an inclined optical system using the above-mentioned optical system 100. The inclined optical system of the present invention will be described in the following.

[0032] As shown in FIG. 3, when the inclined optical system photographs a surface of the object T inclined so that the optical axis X of the lens 10 is at an angle of θ with the surface of the object T, an angle between the image producing surface 60 and the optical axis X is controlled to satisfy the following relations, thus attaining a clear image of the object T.

[0033] As shown in FIG. 4, when it is assumed that: an intersection point between a first main surface L_1 of the lens 10, which faces the object T, and the optical axis X is expressed by a first main point O_1, and an intersection point between a second main surface L_2 of the lens 10, which faces the image producing surface 60, and the optical axis X is expressed by a second main

point O_2; an intersection point between the optical axis X and the object T is expressed by B, a first point set on the object T so that a distance between the first main point O_1 and a foot of the first point is the farthest, is expressed by A, a second point set on the object T so that a distance between the first main point O_1 and a perpendicular foot of the second point is the nearest, is expressed by C, the perpendicular foot of the point A to the optical axis X is expressed by A_0, the perpendicular foot of the point C to the optical axis X is expressed by C_0, a distance between the first main point O_1 and the foot A_0 is expressed by s_2, a distance between the first main point O_1 and the intersection point B is expressed by s_1, and a distance between the first main point O_1 and the foot C_0 is expressed by s_3; and in an image I of the object T produced on the image producing surface 60, an image of the point A is expressed by A', an image of the intersection point B is expressed by B', an image of the point C is expressed by C', a foot of a perpendicular from the image A' to the optical axis X is expressed by A'_0, a perpendicular foot of the image C' to the optical axis X is expressed by C'_0, a distance between the second main point O_2 and the foot A'_0 is expressed by s'_2, a distance between the second main point O_2 and the image B' is expressed by s'_1, and a distance between the second main point O_2 and the foot C'_0 is expressed by s'_3, in the lens 10 having a focal distance f, the distance s'_1 is determined according to a position relation among the lens 10, the tilting shafts 22, and the image producing surface 60 of the optical system according to the present invention. Further, the optical system of the present invention is arranged according to the distance s_1 between the lens 10 and the object T which is controlled to satisfy the following Equation [1].

$$1/s_1 + 1/s'_1 = 1/f \ldots\ldots [1]$$

[0034] Furthermore, the distance adjusting unit 71 is controlled to satisfy either one of the following Equations [2] and [3], thereby controlling an angle between the image producing surface 60 and the optical axis X and obtaining a clear image of the object T.

$$1/s_2 + 1/s'_2 = 1/f \ldots\ldots [2]$$

$$1/s_3 + 1/s'_3 = 1/f \ldots\ldots [3]$$

[0035] According to an aspect of the invention, when the distance s_1 between the object T and the lens 10 and the angle between the image producing surface 60 and the optical axis X are controlled to satisfy all of the above-mentioned Equations [1] to [3], a most clear image of

the object T is obtained. In this case, assuming that an intersection point between a line AC and the first main surface L_1 is expressed by D, and an intersection point between a line A'C' and the second main surface L_2 is expressed by E, a line Y extending through the intersections D and E is disposed parallel to the optical axis X.

[0036] Further, in the Equation [2], the focal distance of the lens 10 is constant. Thus, as the distance s_2 is increased, the distance s'_2 is reduced. To obtain the desired clear image, when the distance s_1 between the object T and the first main point O_1 is increased, the distance s'_1 between the second main point O_2 and the image producing surface 60, on which the image of the object T is produced, must be reduced. In a detailed description, the object T and the image producing surface 60 must be inclined in opposite directions relative to the optical axis X.

[0037] As is apparent from the above description, the present invention provides an optical system in which an angle control unit is controlled according to an angle between an object to be photographed and an optical axis of a lens, thus attaining a clear image of the object. Further, when the object is photographed several times while variously changing the angle between the object and the optical axis of the lens, the angle control unit is controlled according to the angles between the object and the optical axis of the lens, thus attaining clear images of the object. Moreover, the optical system can detect any defected parts disposed on a first portion of the object T between A and B as well as a second portion of the object T between B and C.

[0038] Although an embodiment of the present invention has been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.